Reconstruction of 20 GeV hard jets from pile-up background for case high luminosity

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INTRODUCTION

Efficiency and purity jet reconstruction were considered:

- **for 20 GeV hard jets;**
- **from pile-up background for case high luminosity**
$$L = 10^{34}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1};$$
- **with detailed cms115 version of calorimeter responses;**
- **by window jet finder algorithm.**

SIGNAL AND BACKGROUND EVENTS

Signal events

1000 hard $q+\bar{q} \to q+\bar{q}$ events were generated using subroutine LU2ENT (*PYTHIA5.7*) with $p_\perp = 20$ GeV.
The initial and final state radiation, giving additional gluon scattering was taken into account (subroutine LUSHOW).

Background events

1. 2000 minimum bias background events at $\sqrt{s} = 14$ TeV were generated using standard job including high $p_\perp$ and low $p_\perp$ QCD production (~cms115/examples/cmkin/mb_pyt_ntpl_lsf.job).

- **maximum particles density of charged particles:**

$dN^{\pm}/dy(y=0) = 5.1$ in mid-rapidity region;

- **the average transverse momentum:**

$\langle p_T \rangle = 0.39 \pm 0.45$ GeV - all particles,
$\langle p_T \rangle = 0.53 \pm 0.49$ GeV - $p_T > 0.15$ GeV,
$\langle p_T \rangle = 0.49 \pm 0.50$ GeV - charged, $p_T > 0.15$ GeV

- **multiplicity - all particles:**

$\langle N \rangle = 163.0 \pm 94.4$

2. Signal events and MB events are run separately event by event through CMSIM to produce HITS.

3. Signal event mixing with MB background events is performed at level of digitising.

4. The number of mixed MB events per bunch:

$$\mathbf{N_{mb} = 25}$$

for case high luminosity:

$$\mathbf{L = 10^{34}\ cm^{-2}\ s^{-1}}$$

are defined by default Poisson distribution.

5. Number of pile-up events is equal 1000.

INSTALLATION

CMS calorimeter responses were simulated using full CMS115 version.

For the reconstruction energy deposition in hadron calorimeter were used standard calibration constants:

Barrel: 60.E5, 122.E5, 190.E5, 156.E5
Endcap: 91.E5, 200.E5,

which were determined with $E_T = 50$ GeV pions with GEANT CUTS 1 MeV for electron and gammas and 10 MeV for hadrons.

WINDOW ALGORITHM

The modified window-type jet finding algorithm was used to search "jet-like" clusters above the average energy.

1. All possible rectangular windows (including overlaps) with given radius $R = \sqrt{\Delta\eta^2 + \Delta\varphi^2}$ (window size $= 2R$) in calorimeter map in $\eta-\varphi$ space were constructed.

2. The window energy was calculated as sum of transverse energy cells E_c over all n_c cells included into this window minus background energy per cell:

$$E_{wind} = \sum_{n_c}\{E_c - [\overline{E_c}(\eta) + D_c(\eta)]\},$$

where $\overline{E_c}(\eta)$ — the average transverse energy, $D_c(\eta) = \sqrt{(\overline{E_c^2}(\eta) - \overline{E_c}(\eta)^2}$ — dispersion in cell as function η.

3. The loop on windows starts from the window with maximum transverse energy.

4. The non-overlapping windows with energy $E_{wind} > 2\sqrt{\Sigma\, D_c(\eta)^2}$ are considered as candidates for the jets.

5. Cell with maximum of transverse energy in window is chosen and considered as a center of this jet.

6. Cells of the window within radius R around jet center are collected.

7. $\overline{E_c}(\eta)$ and $D_c(\eta)$ are recalculated using cells which are not covered by jets.

8. The jet energy is calculated as energies of collected cells minus mean background energy per cell:

$$E_{jet} = \Sigma\{E_c - [\overline{E_c}(\eta) + D_c(\eta)]\}.$$

9. We also use criterium on intrinsic structure of a jet, which allow to cut background more effectively. Only jets with the energy density $E(0.7R)/E_{jet} > 0.7$ in center $r < 0.7R$ region of jet are accepted.

RESULTS

I. TRANSVERSE ENERGY MEASUREMENT.

1. Background events.

Dependence of transverse cell energy on value η of cell is observed only in endcap part of calorimeter.

The average values of cell energy (including zero cell):

BARREL — $\langle \mathbf{ET_{cell}} \rangle = \mathbf{0.03 \pm 0.12}$ GeV
ENDCAP — $\langle \mathbf{ET_{cell}} \rangle = \mathbf{0.07 \pm 0.17}$ GeV

The average values of cell energy (without zero cell):

BARREL — $\langle \mathbf{ET_{cell}} \rangle = \mathbf{0.23 \pm 0.33}$ GeV
ENDCAP — $\langle \mathbf{ET_{cell}} \rangle = \mathbf{0.17 \pm 0.25}$ GeV

2. Hard events.

Total measured transverse evergy for hard $q+\bar{q} \rightarrow q+\bar{q}$ events with initial $p_{\perp} = 20$ GeV with standand calibration constants and GEANT cuts:

ET reached CALO $= 36 \pm 4$ GeV,

ET reconstructed in CALO $= 30 \pm 4$ GeV,

energy loss $= 25\%$.

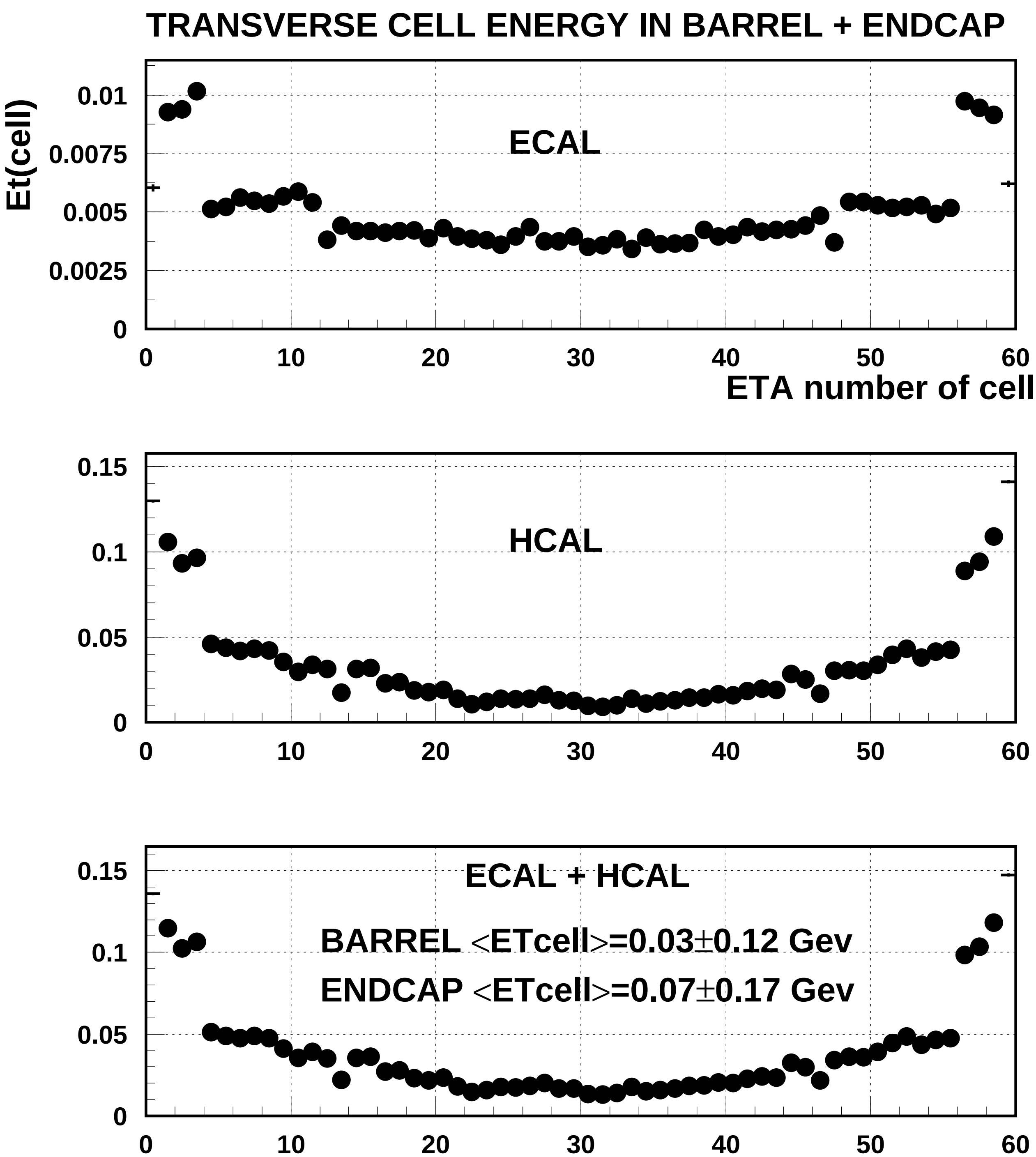


Fig.1 Dependence transverse cell energy on ETA number of cell

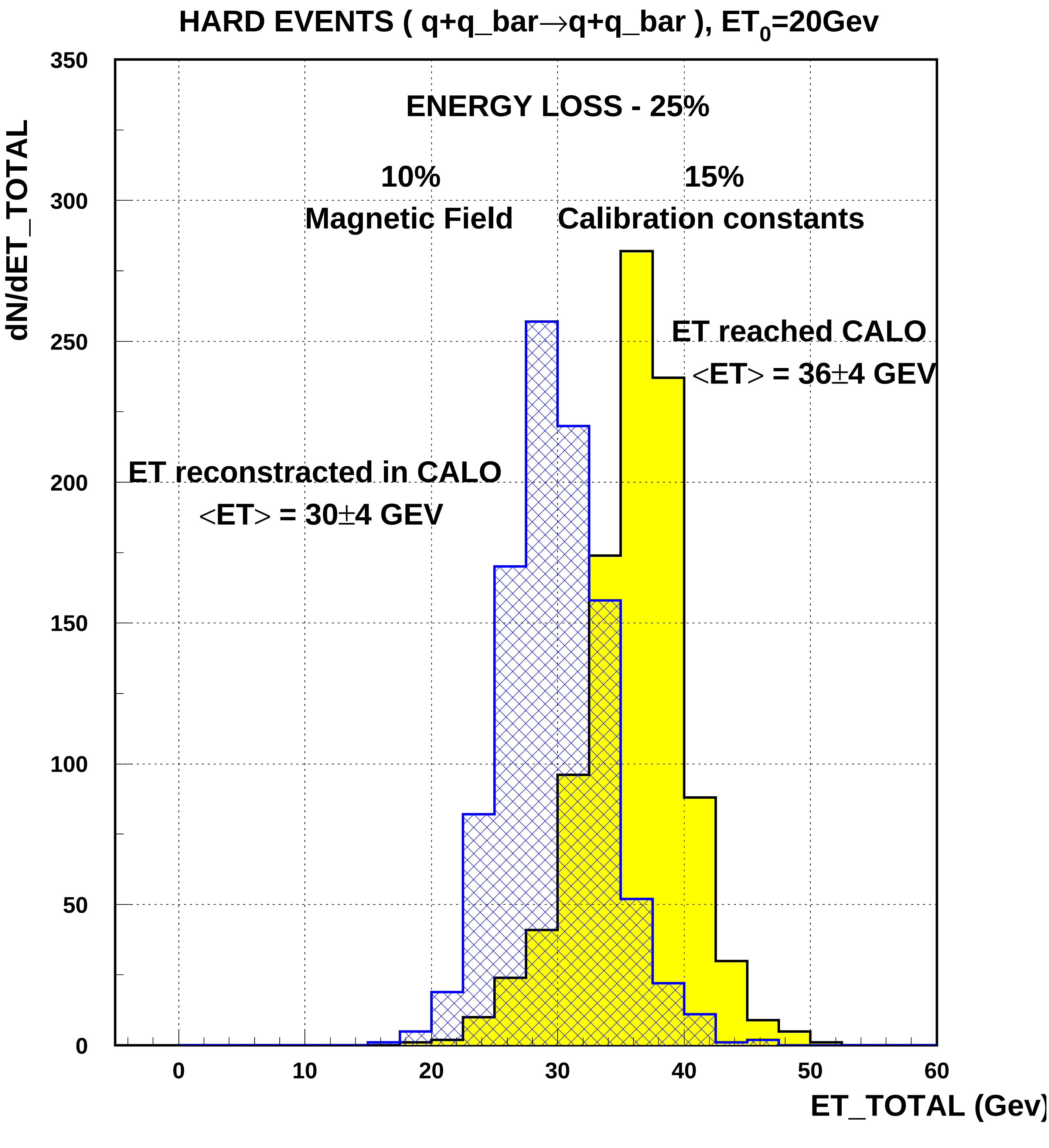


Fig.2 Distributions total energy ET reached calorimeters (solid line) and ET reconstructed in calorimeters (dashed histogram)

II. JET RECONSTRUCTION

Jet reconstruction was studied by WINDOW algorithm in following conditions:

- **hard events $q + \bar{q} \to q + \bar{q}$,**
- **initial energy $E_T = 20$ GeV,**
- **without background and with background from pile-up events (high luminosity),**
- **cut on window energy: $E_{wind} > 5$ GeV,**
- **only jet with maximal energy in event were used for further analysis.**

Measured jet energy in events for QUARK jets (initial and final state radiation is switched on) with $R = 0.7$:

$\langle ET_{jet} \rangle = 13.2 \pm 3.0$ GeV — without background,

$\langle ET_{jet} \rangle = 13.6 \pm 4.0$ GeV — with background.

For false jet from background events:

$\langle ET_{jet} \rangle = 6.0 \pm 4.9$ GeV.

JET RECONSTRUCTION EFFICIENCY

$$\text{Efficiency} = \frac{\text{Number of events with reconstructed jet}}{\text{Number of generated events}}$$

Efficiency and energy of reconstructed jets were determined for the different radii R window algorithm.

Table 1.

Initial and final state radiation is switched off.

R	Efficiency (%)	E_t jet (GeV) with background	E_t jet (GeV) without backgrond
0.4	99	11.7 ± 4.1	13.0 ± 3.0
0.5	99	13.3 ± 4.0	14.0 ± 3.0
0.7	98	15.8 ± 4.2	15.2 ± 2.7
1.0	98	20.0 ± 5.2	16.1 ± 2.6

Table 2.

Initial and final state radiation is switched on.

R	Efficiency (%)	E_t jet (GeV) with background	E_t jet (GeV) without backgrond
0.4	99	10.0 ± 4.4	11.3 ± 3.3
0.5	99	11.4 ± 4.2	12.0 ± 3.2
0.7	99	13.9 ± 4.4	13.3 ± 3.1
1.0	99	18.3 ± 5.3	14.4 ± 3.0

JET PURITY

In order to define, what is true jets, we compared the reconstructed jets from events with and without background.

1. We reconstructed jet with maximal energy in event without backgroound and mark the corresponding cells.

2. We reconstructed the same jet in the event with background and determined the number of cells overlapping with case (1).

Dependence of the fraction of events with given percentage of overlapping cells on this percentage are shown on fig. 3, fig. 4 and table 3.

Table 3. (R=0.7)

Fraction of overlapping cells(%)	Fraction of events (%)	Purity (%)
a) Initial and final state radiation is switched off		
> 60	87.1	87.1
< 60	9.9	
0	3.0	
b) Initial and final state radiation is switched on		
> 60	80.0	80.0
< 60	16.1	
0	3.9	

Let's define the true reconstructed jet as a jet with more than 60% of overlapping cells.

$$\text{Purity} = \frac{\text{Number of events with true jet}}{\text{Number of events with all reconstructed jets}}$$

pp (q+q_bar→q+q_bar), Et=20GeV, high luminosity, IFS-switched off

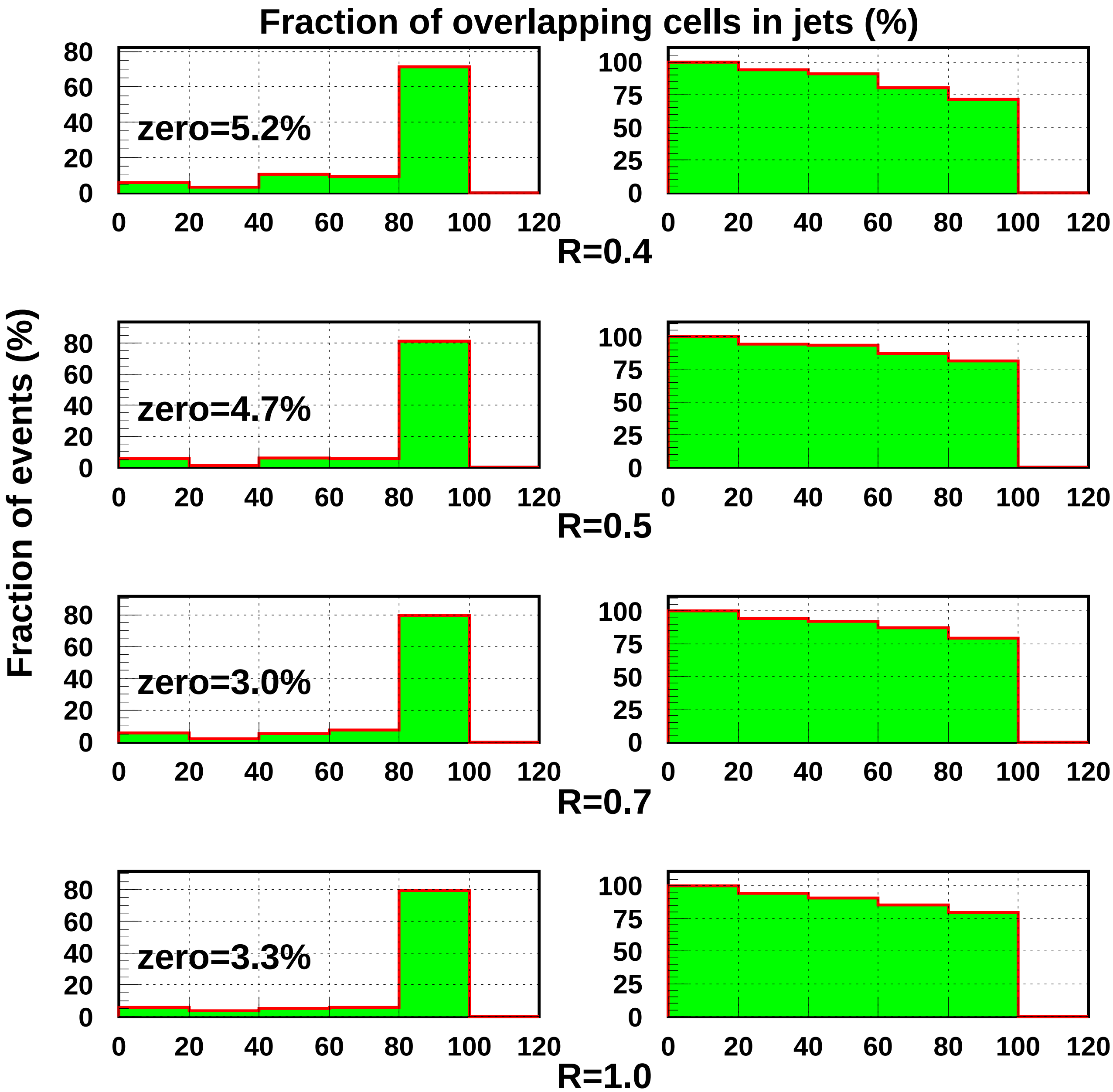


Fig.3 Dependence of the fraction of events with given percentage of overlapping cells on this percentage for different radius R window algo. Differential (left) and integral (right) distributions. Zero-fraction of events without overlapping cells.

pp (q+q_bar→q+q_bar), Et=20GeV, high luminosity, IFS-switched on

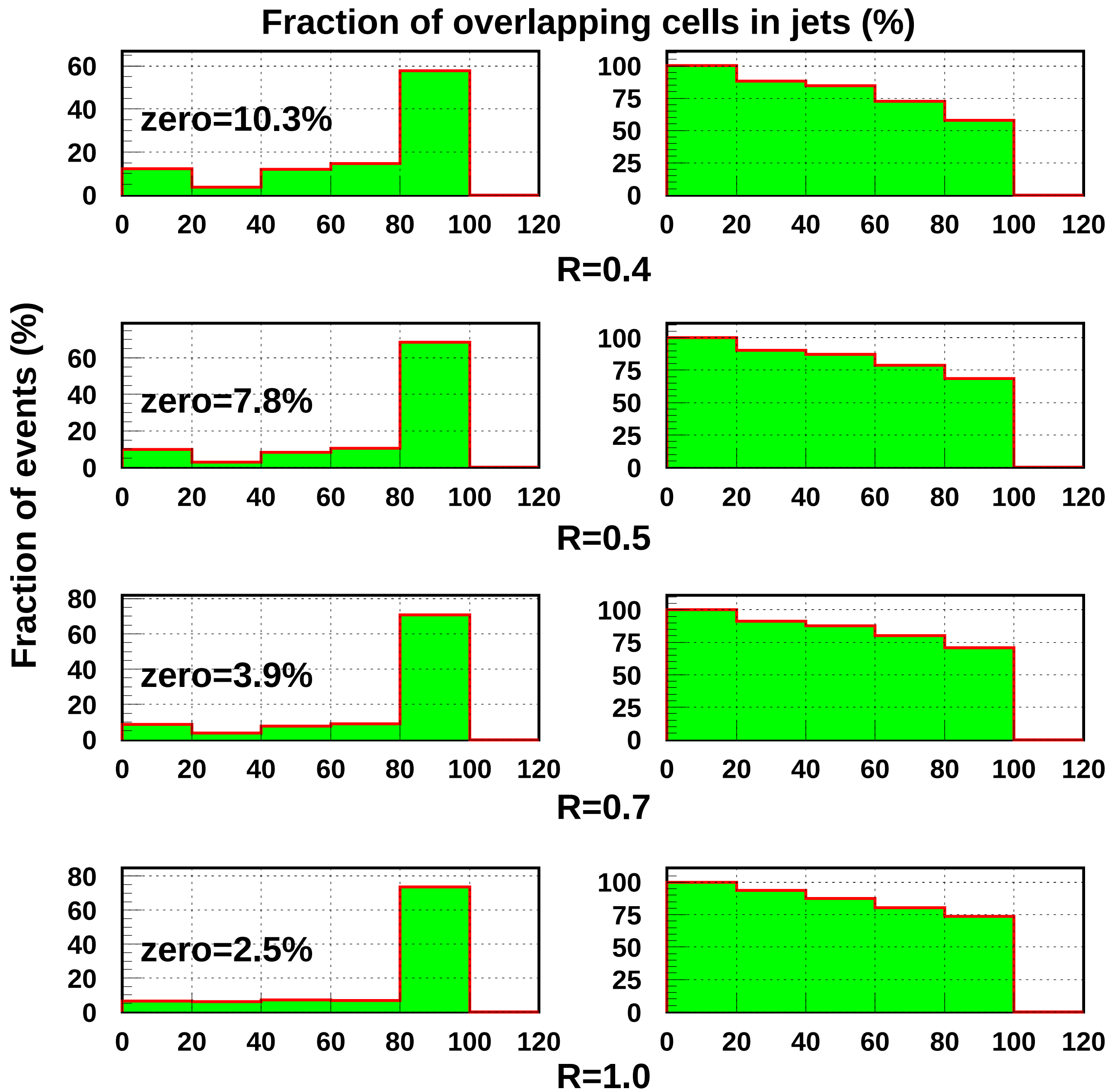


Fig.4 Dependence of the fraction of events with given percentage of overlapping cells on this percentage for different radius R window algo. Differential (left) and integral (right) distributions. Zero-fraction of events without overlapping cells.

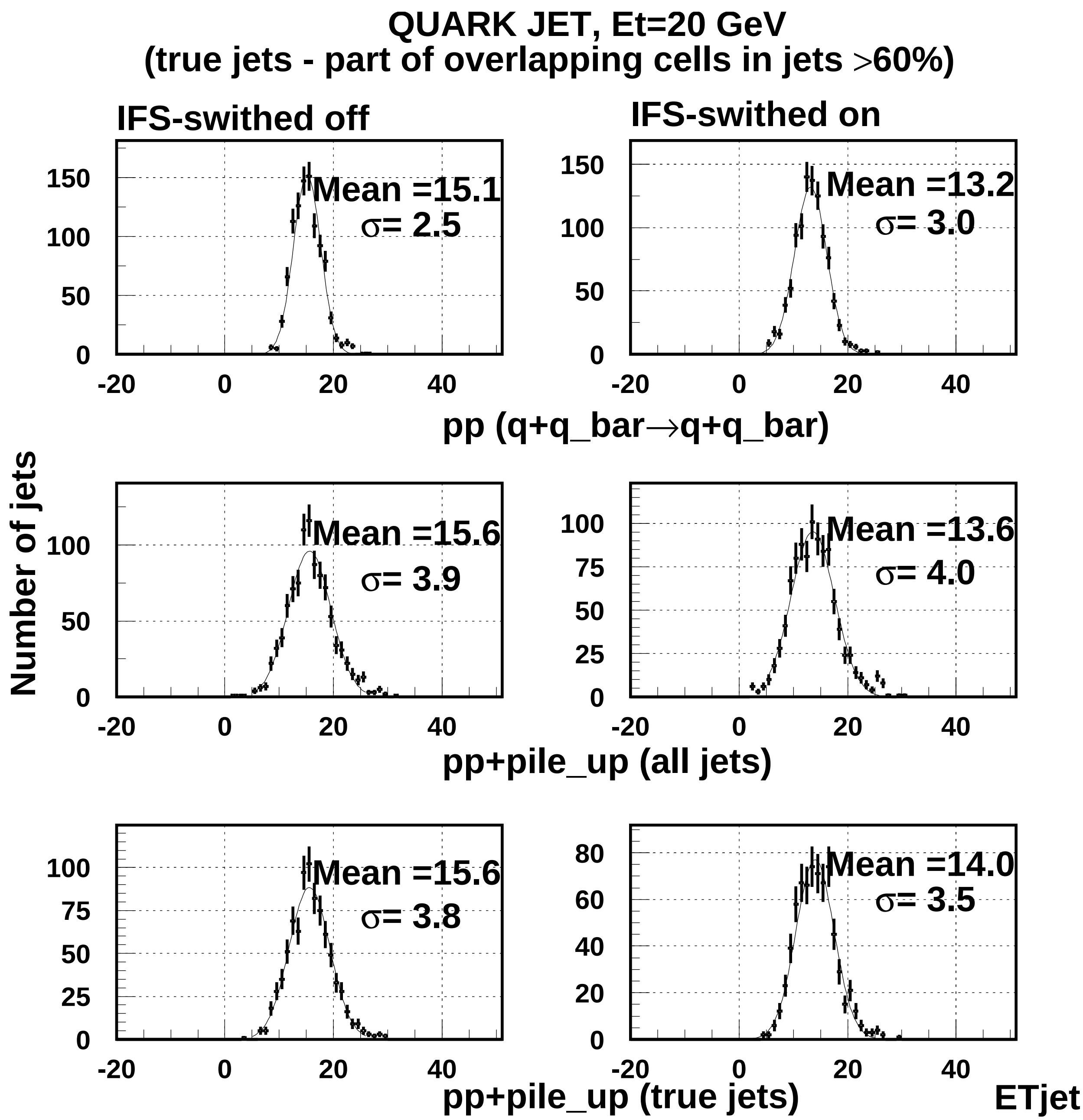


Fig.5 Energy distribution for jets reconstructed in pp, pp+pile_up (all jets) and pp+pile_up (true jets) events, than IFS is swithed off (left histograms) and IFS is swithed on (righ histograms)

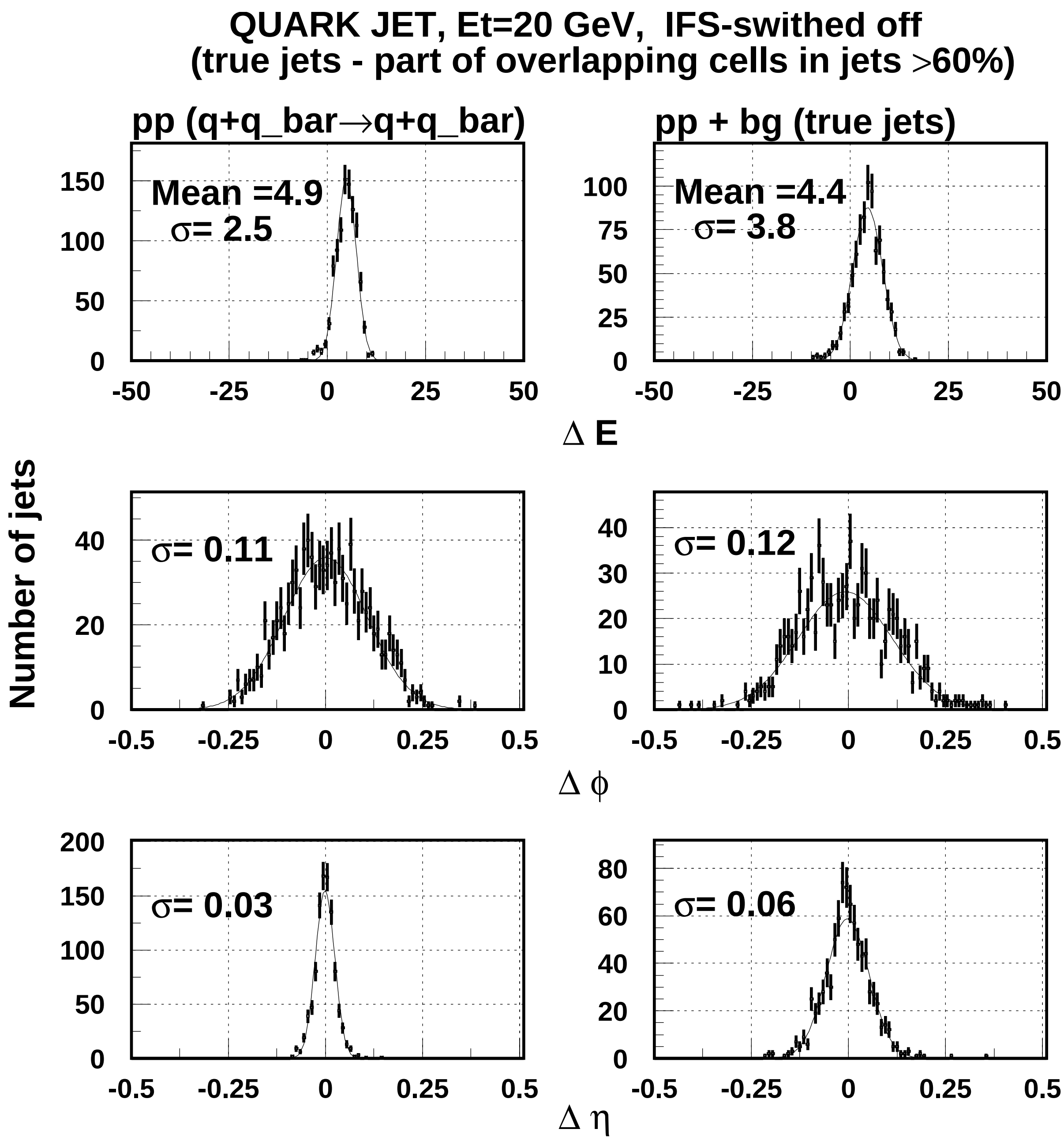


Fig.6 Differences in transverse energy, pseudorapidity and azimuthal angle between the simulated and reconstructed jets by window algorithm with R=0.7

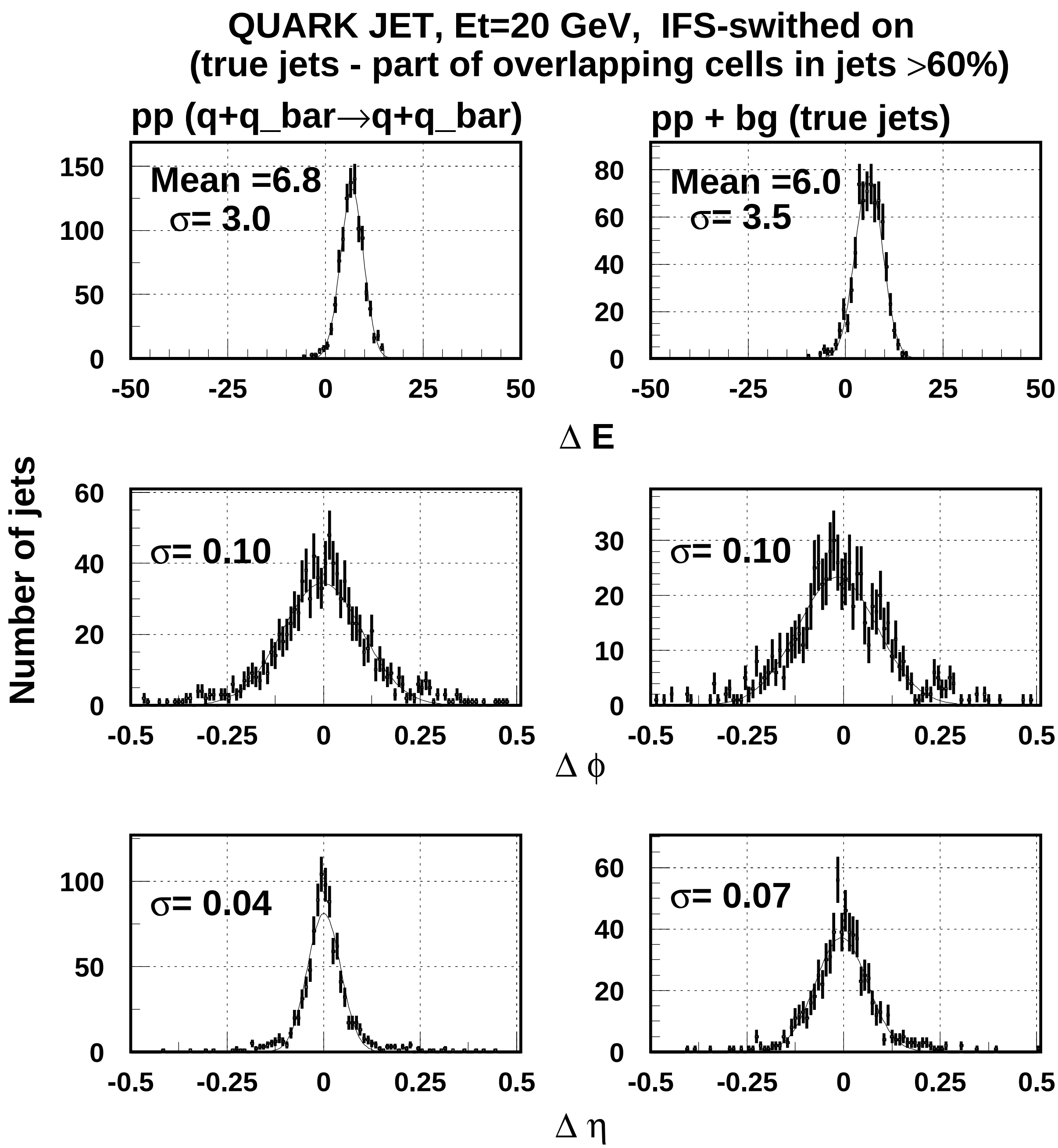
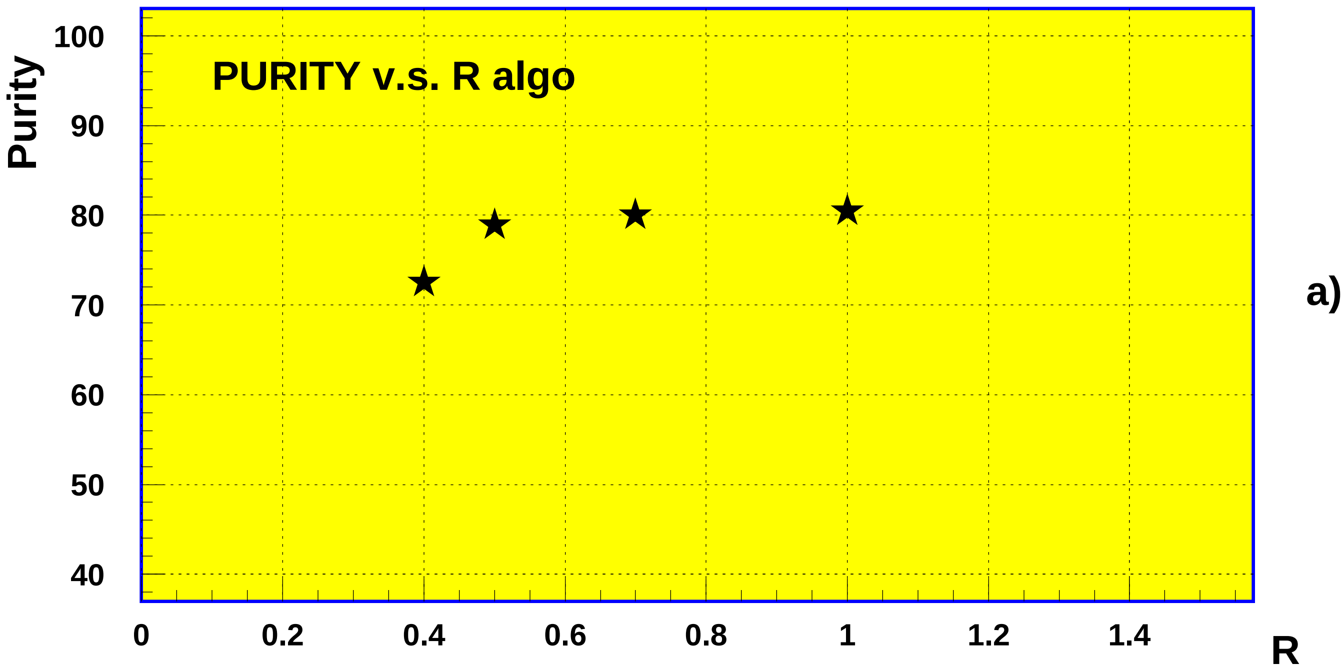


Fig.7 Differences in transverse energy, pseudorapidity and azimuthal angle between the simulated and reconstructed jets by window algorithm with R=0.7

RECONSTRUCTION 20 GEV JETS FROM PILE_UP BACKGROUND
(IFS is switched on)



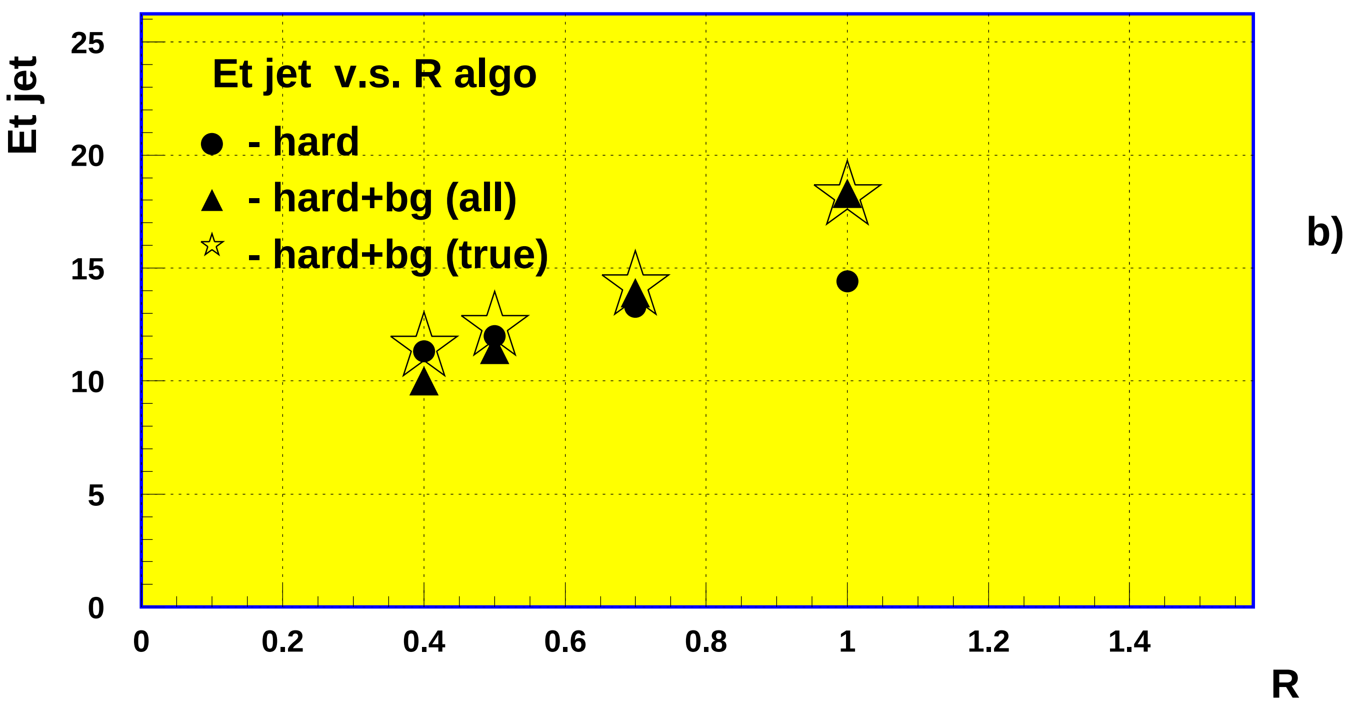


Fig.8 Dependence of purity (a) and measured jet energy (b) on radius R window algorithm

CONCLUSION

Jet reconstruction by WINDOW algorithm for hard $q + \bar{q} \to q + \bar{q}$ events with initial $p_\perp = 20$ GeV from pile-up background for case high luminosity were considered.

For radius R=0.7 window algorithm:

1.Initial and final state radiation is switched off.

With efficiency 98% and purity 87% jets were reconstructed.

For true jets measured energy:

$\langle ET_{jet} \rangle = 15.1 \pm 2.5$ GeV without background
$\langle ET_{jet} \rangle = 15.6 \pm 3.8$ GeV with background

2.Initial and final state radiation is switched on.

With efficiency 99% and purity 80% jets were reconstructed.

For true jets measured energy:

$\langle ET_{jet} \rangle = 13.2 \pm 3.0$ GeV without background
$\langle ET_{jet} \rangle = 14.0 \pm 3.5$ GeV with background

We define the true reconstructed jets as a jets with more than 60 of overlapping cells.

If define the true jets as a jets with any amoumt overlapping cells, (excepted only ero overlapping cells) then

purity 9 (without I S),

purity 96 (with I S)